UNITED STATES TARIFF COMMISSION
WASHINGTON

INFORMATION

CONCERNING

TUNGSTEN-BEARING ORES

PRINTED FOR USE OF

COMMITTEE ON WAYS AND MEANS

HOUSE OF REPRESENTATIVES

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UNITED STATES TARIFF COMMISSION.

Office: 1322 New York Avenue, Washington, D. C.

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LETTER OF TRANSMITTAL.

UNITED STATES TARIFF COMMISSION,
Washington, June 14, 1919.

The Committee on Ways and Means, House of Representatives:

I have the honor to transmit herewith, in accordance with your request, information compiled by the United States Tariff Commission on tungsten-bearing ores.

Very respectfully,

THOMAS WALKER PAGE,
Acting Chairman.

INTRODUCTORY STATEMENT.

Tungsten mining was an industry that was profoundly affected by the war. In June, 1918, two conferences were held by the United States Tariff Commission—one in Denver and one in San Francisco—at which the producers, consumers, and importers of the ore and metal were given an opportunity to present their views as to the permanent aspects of the industry.

The domestic production of tungsten-bearing ore increased under the stress of war necessity to nearly five times the output before the war. The signing of the armistice found large accumulations of ore and ferro-tungsten in this and foreign countries; and the closing of munition plants, which had been the largest consumers of tungsten steel, caused a temporary reduction in the demand for tungsten products. The result of these circumstances was a chaotic condition of the market which was aggravated by heavy importations of foreign ore released from licensing regulations.

Tungsten mines throughout the United States have been closed down and domestic production is at a standstill; but the influx of foreign supplies has continued unabated and has inhibited readjustment of the American industry to a peace basis. Consumption is becoming adjusted, but prices are at a level that does not permit the successful operation of American mines. Reports indicate the discovery of large new supplies of ore in southern China, and that the flood of ore from that section is partly present production, and not merely a liquidation of stocks accumulated during the war period.

TUNGSTEN-BEARING ORES.

I. SUMMARY.[1]

DESCRIPTION.

There are four commercial tungsten minerals, scheelite, ferberite, huebnerite, and wolframite. Scheelite is the tungstate of lime. The other three are frequently grouped together as the wolframite series, ranging in composition from ferberite (tungstate of iron) to huebnerite (tungstate of manganese). The pure minerals of the wolframite series contain over 76 per cent tungsten trioxide (WO_3). Scheelite contains about 80 per cent WO_3. The tungsten ore of commerce, however, contains a certain amount of nontungsten bearing material in addition to one or more of the above minerals. The standard ore contains 60 per cent WO_3 and this tenor is usually obtained by concentration of low-grade ore.

USES.

Practically all the tungsten ore now produced in the world is used in the making of tungsten metal or ferrotungsten. Various salts of tungsten have been employed in the dye industries, but have been almost wholly replaced by cheaper chemicals. Over 95 per cent of the tungsten production goes into the making of tungsten steel, which is in general use for high-speed cutting tools, permanent magnets, and saw blades. A small amount of very pure tungsten is consumed in the making of filaments for incandescent electric lights.

DOMESTIC PRODUCTION.

Quantity.—The maximum domestic production of tungsten ore, expressed in terms of concentrates containing 60 per cent WO_3, was 5,900 short tons, in 1916. The 1917 output was 4,633 short tons. The valuations for the respective years were $24,780,000 and $5,932,000. Preliminary reports indicate that the 1918 output was 5,046 short tons.

Mining methods.—Some tungsten is obtained by placer mining, especially in foreign countries. Most of the domestic production is obtained from lode deposits. In new districts the ore may often be picked up on the surface of the ground or gouged out from shallow open workings. Such cheaply obtained material is largely exhausted in the United States and most of the domestic production now comes from underground workings. These are of two types, which may be designated narrow or wide. The narrow deposits are typified by the stringer lodes of Boulder County, Colo. The lodes of the Southwest are usually wider and can be worked on a larger scale.

[1] This first section, under "Summary," is to be regarded merely as a condensed abstract of what follows under "General Information" in later section.

Concentration.—The mechanical treatment of low-grade tungsten ore has reached its highest development in the United States. American mills are better equipped than those in foreign countries and obtain a more nearly complete extraction of the values. Tungsten ore has a strong tendency to slime. This tendency is minimized by stage reduction and improved machinery for the recovery of fine material.

Equipment.—In the early stages of production practically no equipment is required, as the work consists largely of collecting the ore and hand sorting; but when deep mining begins, power plants, pumps, hoists, air compressors, and other machinery must be installed and considerable capital expended in development work. The treatment of a large tonnage of low-grade material requires expensive crushing and concentrating machinery.

Organization.—The tungsten industry is characterized by a large number of small independent producers with only a few well-financed companies. A considerable number of the stronger operators have connections with manufacturers or consumers of tungsten metal and ore. The Atolia Mining Co. of California [1] is the largest producer in the United States, and its output constitutes over 30 per cent of the total domestic product. Fully 75 per cent of the tungsten mined in the United States is taken out by four large companies, the Atolia in California and the Primos Chemical Co., the Wolf Tongue M. & M. Co., and the Tungsten Products Co., in Boulder County, Colo. The remaining 25 per cent comes from a large and constantly shifting group of small operators.

Localities of production.—Tungsten deposits are actively exploited in the Mojave Desert and at Bishop, Calif.; in Boulder County and Silverton, Colo.; in various counties in Nevada; in Arizona; and in the Black Hills of South Dakota. A sporadic production has come from sections in the above States other than those specifically mentioned and from Idaho, Washington, Oregon, New Mexico, Utah, Missouri, and Connecticut. In the last few years California and Colorado have contributed approximately 90 per cent of the total output of the United States and in about equal proportions. The Atolia district in the Mojave Desert is the largest producer of scheelite in the world.

Domestic production and domestic consumption.—The domestic production of tungsten ore furnished less than 50 per cent of the domestic requirements in 1917 and a probably still smaller percentage in 1918. Previous to the Great War about 75 per cent of the domestic supply came from American mines, but the consumption has increased more rapidly than the production.

The ratio of the consumption to the production of tungsten ore is not strictly an index of the tungsten requirements of the country. The imports and exports of tungsten powder and ferrotungsten must also be considered. In the prewar period some tungsten was imported in the form of ferro-alloy; but since 1914 practically all the imports have been of ore. In 1917 the United States exported large amounts of ferrotungsten and tungsten powder. The actual ratio of consumption to the production of tungsten metal has, therefore, not increased quite so rapidly as has that of the ore; nevertheless, a less proportion of the total tungsten actually used for the

[1] Not connected with tungsten manufacturers.

making of finished steel and other products (ultimate tungsten consumption) is now produced in this country than in the years preceding the war.

Domestic exports.—Very little of the United States production of tungsten ore has ever been exported. A small amount was shipped to Germany in 1910 to 1914. No records are available as to the exact amount, but it was never large. In the last year or two there has been some export of ferrotungsten, especially to Italy, but the continuance of these exports is not dependent on domestic production of ore as this metal could be, and probably to a large extent is, reduced from imported ore.

FOREIGN PRODUCTION.

Countries of largest production.—Burma (including the Shan States) is the largest producer of tungsten ore in the world and in 1917 produced 21.4 per cent of the world output. The United States was the second largest and produced 17.1 per cent of the total for that year. Bolivia was third with an output equivalent to 15.8 per cent. In 1917, 41.8 per cent of the world supply was drawn from Asia; 22.2 per cent from South America; 18.4 per cent from North America; 11.3 per cent from Europe, and 6.3 per cent from Australia and New Zealand. Africa produced only a negligible amount. These figures indicate, as experience has shown, that tungsten is widely distributed over the earth's crust, but in no place is it found in very great amounts.

Tungsten industry in foreign countries.—Most of the Asiatic supply comes from surface deposits. Broadly speaking, especially in Burma and contiguous territory, the cream of this easily gathered material has been skimmed as evidenced by increased costs in spite of the cheap labor employed. The only exceptions are certain sections of China and Korea. The Bolivian production comes chiefly from deep mines where it is found associated with tin.

In general, the costs of foreign production—even including freight to the United States—are lower than the costs of production in the United States. This is due not only to cheaper labor but also to the fact that a larger proportion of foreign ore comes from near the surface.

IMPORTS.

From 30 to 50 per cent of the United States supply of tungsten ore is imported. In general the foreign ore is not so free from objectionable impurities as is the American product, and, therefore, sells at a discount from the American quotations. Some of the imported ore, however, compares favorably in regard to purity with the domestic. As a rule, it has a higher tungsten content, frequently running up to 65 or 70 per cent. Ore containing as little as 50 per cent WO_3 is imported, but the average grade of imported ore is in the neighborhood of 60 per cent.

Germany was the trading center of the tungsten industry before the war and most of the prewar imports of the United States were shipped from Germany. Only a fraction of these imports originated in Germany but represented a German brokerage business. When

Germany was cut off from world communication, imports came direct from the countries of origin, especially from South America and Asia. Another feature of the shortening of the routing of imports was the practical cessation of the importation of tungsten metal and ferrotungsten. The tungsten supply of the United States is now derived almost exclusively from ore, whereas German-made ferro-alloy formerly represented an important fraction of the imported supply.

There are no tungsten reduction plants on the Pacific slope so the ultimate destination of ore is along the Atlantic seaboard. Due to the transfer of sources of supply from Europe to South America and Asia, an increasing amount of material has arrived at Pacific ports. The transcontinental freight ($42.50 a ton in 1918) to the Eastern States is not a very large item as compared to the cost of so expensive a commodity (valued at $1,000 to $1,500 a ton), and it is partially offset by nearness of centers of consumption of the ferro-alloy.

Revenue.—The maximum revenue collected in the form of duties on tungsten ores was less than $39,000. This was in 1913 [1] under a tariff of 10 per cent ad valorem. Since tungsten ore has been imported free of duty during the war period, the imports have furnished no revenue, although their value in 1917 [1] was nearly 13 times as great as in 1913.[1]

PRICES.

The price of tungsten ore is quoted in the United States in terms of the value of a short ton unit (20 pounds) of tungsten trioxide (WO_3) and based on material containing 60 per cent WO_3 and no objectionable impurities. Unless otherwise specified, the quotation is for wolframite. Scheelite and ferberite are worth a little more and huebnerite a little less than wolframite in concentrates of the same tungsten tenor. A small premium is paid for ore of higher grade than 60 per cent and there is a discount off the unit price for lower grade material.

The price history of tungsten is characterized by extreme fluctuations. There was a general advance in price from about $2 a unit in 1900 to a little more than $7 a unit in 1914. In the winter of 1915–16 there was a "boom" in tungsten. The price soared to over $90 a unit in a period of about six months. Then followed a spectacular fall to $25 and later $18 all within less than three months. Since September 1916, the price has remained in the range $18 to $26, averaging about $22 a unit.

The chief factor regulating price in the United States has been the amount and convenience of importation.

The British Government fixed a price of 55s. ($13.365) per long ton unit (22.4 pounds) early in the war. This was later raised to 60s. ($14.60). These prices are considerably lower than those obtaining in all other markets and are maintained only by embargoes on shipments from British ports. The present price of 60s. corresponds to $13.04 a short ton unit and is based on a 65 per cent WO_3 content instead of 60 per cent as in the United States.

[1] Fiscal years.

TARIFF HISTORY.

Tungsten ores and concentrates are admitted free of duty under paragraph 633 of the act of 1913. Previous to the act of 1909, tungsten ores were not specifically mentioned in the tariff law and were held to be exempt from duty as a crude mineral. The act of 1909 specifically mentioned tungsten ores and imposed a duty of 10 per cent ad valorem. Following the complete removal of the duty, in 1913, the imports fell off 50 per cent. Other factors in the industry were more important at that time, and it was not until 1916 that foreign ore poured into the United States and again became a serious competitive factor in the market.

TARIFFS IN FOREIGN COUNTRIES.

Tungsten ore is not specifically mentioned in the tariff laws of any European countries or Canada.[1] It therefore comes under the blanket clauses covering metallic ores of all kinds which are generally admitted free of duty. Export tariffs are levied on tungsten ore in Portugal and many of the South American countries. This tax in Portugal is $1.07 a unit and in Bolivia about $0.13 per long-ton unit, plus one-tenth of 1 per cent ad valorem.

TARIFF QUESTIONS INVOLVED.

The tungsten production of the United States has suffered a relapse from the greatly expanded output of the war period. The cheap, easily mined resources of this material are practically exhausted, and a continuation of production depends upon the development of underground operations which require a considerable investment of capital. While it has not yet been fully demonstrated that the domestic deposits can long continue a large production, the data that are available indicate that they can furnish a substantial amount for some time. The demand for tungsten is not purely a war condition. The effect of the war was merely to emphasize the necessity for tungsten steel tools as a factor in industrial efficiency. Only a very serious and general business depression would cause a serious slackening in the consumption of tungsten.

The investment of the capital necessary to equip and develop tungsten mines in the United States is hindered by a serious doubt as to whether the present, or in fact any, stabilized price will be maintained. There are producers in the United States that can market tungsten at $10 a unit, but an important part of the present production comes from mines where such low costs are impossible because of the erratic character or low grade of the deposits. At the tungsten conferences held by this commission in Denver and San Francisco in June, 1918, the most important feature of the entire situation was stated by all producers to be the necessity of a stable price high enough to meet the costs of operating mines of the less favored group.

[1] Great Britain, France, Italy, Spain, Portugal, Norway, Sweden, Austria-Hungary, and Germany, Kelly's Customs Tariffs of the World, 1918;.

A large part of the foreign production comes from comparatively new fields of high-grade ore that requires only to be picked off the ground. This condition existed in the United States up to about 1915, and the cost of production was less than $7 a unit even under the high wage scale obtaining in this country as compared to that in many foreign countries. Similar deposits in foreign countries can be expected to reach the same condition eventually, but for a time they are able to supply tungsten c. i. f. American ports at considerably lower figures than the American mines.

A considerable duty on tungsten ore would encourage the investment of capital in tungsten mining and a continuance of production from American mines. Under the present free importation of tungsten ore the domestic production will remain dormant and can not be expected to recover until the deposits of foreign countries are depleted to at least the same extent as those in the United States. The world price will then rise to above the cost of production in the United States and the American deposits can be worked. An important result of a duty would be the development of the comparatively low-grade, but probably extensive, deposits of the Southwest.

The domestic production can not be expected to indefinitely supply the domestic needs. It must be supplemented by imported ore.

The export trade in ferrotungsten and tungsten metal would not of necessity be affected by a duty on the ore, since the reduction of South American and Asiatic ore could be conducted in bond, just as the smelting-in-bond business is conducted on ores of lead and zinc.

Another factor that must not be lost sight of is the necessity of placing a compensatory duty on imports of tungsten metal, powder, and salts, ferrotungsten, high-speed steel, and other tungsten products, in case a duty be placed upon the ore. Under the act of 1913 these products are dutiable, but the duties were adjusted on the basis of the free entry of the raw material, i. e., with tungsten-bearing ore on the free list.

U. S. TARIFF COMMISSION CONFERENCES, 1918.

[Digest of opinions.]

The salient feature brought out in every brief and verbal statement submitted in the conferences at Denver and San Francisco in June, 1918, was the anxiety of producers as regards price. The development of properties, the exploitation of new mines, the erection of concentrating mills, and in fact all the requisites for the continuance of production of tungsten ore are handicapped by the real doubt in the minds of those able to furnish the necessary capital to do these things, whether or not an adequate price can be maintained after the war. The present widespread consumption of tungsten is not going to decrease, but will increase. The United States has a sufficient supply to meet its requirements for many years to come. Although many, even most, of the producers—real and potential—can not compete with the foreign production from surface deposits, they claim to be able to put tungsten ore on the market in adequate amounts at a reasonable price which will not handicap the consumers

of their product, provided they are assured of this reasonable price (by protection, either through tariff or other means) for a number of years.

Tungsten is a vital necessity to the country in war and peace. The cheap sources of supply are rapidly disappearing in all parts of the world, and it may eventually become necessary to supply all our needs from domestic mines. It was claimed that if the domestic producers are not protected from foreign supplies that are likely to flood the country as soon as embargoes and other war limitations to shipping are removed, many of them would be forced to shut down their properties and allow them to deteriorate to such an extent that resumption of production would be difficult in the extreme.[1]

The census of Colorado producers revealed the general sentiment that a maintenance of present production could not be assured at a lower price than $30 to $40 a unit. The California and Nevada sentiment was not so extravagant and indicates the greater dependability of the industry in that section. A price of $28 to $30 was generally desired, but there was a strong undercurrent of sentiment that a positively stabilized price of at least $25 a unit would effect the expansion of the industry in the Southwest.

Summary Table.

Calendar year.	Domestic production (long tons).[2]	Imports for consumption (long tons).[3]	Domestic exports.	Ratio to production: Imports (per cent).	Value (imports for consumption).	Amount of duty.	Value per unit of quantity per long ton.	Equivalent ad valorem rate (per cent).
1910	1,626	([4])	([5])	.....	[6] $178,174.00	[6] $17,817.40	.....	10.00
1911	1,017	([4])	([5])	.....	85,887.00	8,588.70	.....	10.00
1912	1,187	736	([5])	62.04	362,422.00	36,242.20	$492.20	10.00
1913	1,372	401	([5])	29.23	213,122.00	[7] 13,869.60	531.70	10.00
1914	884	267	None.	30.20	139,687.00	Free.	523.20	.....
1915	2,082	1,370	None.	65.80	1,044,986.00	Free.	762.80	.....
1916	5,268	3,547	None.	67.33	7,353,691.00	Free.	2,074.20	.....
1917	4,137	4,354	None.	105.24	4,465,590.00	Free.	1,025.60	.....
1918	4,505	10,491	None.	232.87	11,552,218.00	Free.	1,101.16	.....

[1] This prophesy has since been fulfilled.
[2] Calculated into equivalent tons of 60 per cent WO_3.
[3] Not corrected. No data as to equivalent tons of 60 per cent WO
[4] Weights not recorded prior to July 1, 1911.
[5] No statistics.
[6] Six months ending Dec. 31, 1910.
[7] Duty from Jan. 1 to Oct. 3, 1913, under act of 1909.

II. GENERAL INFORMATION.

DESCRIPTION.

Tungsten metal is never found native but occurs in nature only in the form of tungstates of iron, manganese, or calcium. The minerals are most often found in acid rocks (cf. granite or rhyolite), especially in pegmatite dikes. Except in the United States, it is usually accompanied by tin ore in veins or placer deposits resulting from the erosion of lode formations and from the concentration in stream beds of the heavier constituents of country rock.

Wolframite or iron-manganese tungstate, (FeMn) WO_4, is the most common ore of tungsten. It occurs in long, dark-brown to black crystals or short columnar masses, with a dark brown streak. The hardness is about 5, or a little less than that of steel. It generally contains approximately 76.4 per cent of tungsten trioxide (WO_3), but, as the name is used to include all variation in composition from pure iron tungstate (ferberite) and pure manganese tungstate (huebnerite), the tungsten content varies slightly as does the specific gravity between the values for the respective components.[1]

Ferberite or iron tungstate, $FeWO_4$, is a dull coal-black mineral, sometimes occurring in aggregates of cubic crystals, but more often massive as black sooty material in veins in pegmatite. After exposure to the action of the weather, ferberite is often so impregnated with iron oxide as to appear brown even along a fracture surface. The specific gravity is 7.5 and the hardness 5. Ferberite is the common ore in Boulder County, Colo., but has not been found in commercial quantities in other parts of the world. It is valuable ore in that district, and the pure mineral contains 76.3 per cent tungsten trioxide.

Huebnerite (hübnerite) or manganese tungstate, $MnWO_4$, is a reddish brown mineral of about the same hardness as ferberite. The specific gravity is about 7.2, or a little less than that of the iron mineral. It is found typically in needle-like crystals in quartz. The theoretical content of tungsten trioxide is 76.6 per cent. The appearance of huebnerite, like that of ferberite, is likely to be obscured by the action of weathering, and the mineral in surface exposures is generally coated with black oxide of manganese or brown iron oxide.

Scheelite or calcium (lime) tungstate, $CaWO_4$, is a totally different mineral from the wolframite series. The color varies from nearly pure white to yellow or gray, but always light. Scheelite has not the metallic appearance of the wolframite series and most other metallic minerals but has a stony look more like quartz feldspar or marble. It is best distinguished from gangue minerals by its greater specific gravity (about 6) and it has a greasy luster that is very characteristic,

[1] The following classification suggested by F. L. Hess of the U. S. Geological Survey has been adopted by some writers and deserves wider recognition: Ferberite, iron tungstate with not more than 20 per cent of manganese tungstate; huebnerite, manganese tungstate with not more than 20 per cent of iron tungstate; wolframite, all mixtures iron tungstate and manganese tungstate between the above limits.

especially on a freshly broken surface. Scheelite is a little softer than the minerals of the wolframite group (hardness about 4.5) but is harder than calcite. Pure scheelite contains 80.6 per cent tungsten trioxide (WO_3), the highest content of all tungsten minerals.

The value of all tungsten ore depends on its contents of tungsten. This is invariably expressed in terms of tungsten trioxide (WO_3) or tungstic acid (as it is generally, though erroneously, called). The ore as mined rarely contains more than a very small WO_3 content and requires to be concentrated before it can be utilized as a commercial product. The standard "ore" is therefore a concentrated product containing approximately 60 per cent tungstic acid. Quotations are given in terms of dollars per unit. The "unit" is 1 per cent in a ton of total material, and represents either 20 pounds or 22.4 pounds of the valuable constituent, depending upon whether the short ton or long ton is referred to.

HISTORY.

The tungsten mineral wolframite was known in the tin mines of Saxony-Bohemia region, and later in Cornwall, long before the element tungsten itself was discovered.

In 1781 the Swedish chemist Scheele discovered a new mineral acid; the stony mineral discovered later was named scheelite in his honor, while the element he discovered was afterwards named tungsten from the two Swedish words "tung," heavy, and "sten," stone. In Great Britain and its Provinces the word "wolfram" has been compelled to do duty for both mineral and metal, but there is now a distinct trend to the better usage of calling the metal tungsten and the mineral wolframite.

In 1785 the D'Elhujar brothers found that wolframite also contained tungsten and established the relation of scheelite to wolframite. They also succeeded in obtaining metallic tungsten from the oxide and were probably the first to reduce the metal from its compounds.[1]

The valuable properties imparted to steel by the addition of tungsten were recognized about 1855 and in 1857 a steel maker named Mushet took out the first patent in England for its use. A few years later the manufacture of a 25 per cent alloy was begun in Germany. This early ferrotungsten was made in crucibles on a very small scale and was very impure. The use of tungsten on any large scale in the making of alloy steel was insignificant until the twentieth century. Small amounts of ore were made into chemicals but tungsten and its ores were very unimportant commodities.

The first lot of domestic ore known to have been produced and sold in the United States was in 1900. The price was then about $2 a unit. Since 1901 the growth of the tungsten industry has been fairly rapid. Germany was the chief market for ore and a large part of the world output was shipped there, to be reduced to metal or ferroalloy or exported to other countries.

The history of the mining of tungsten in every country shows a marked similarity. Although the occurrence of tungsten is widespread, the individual deposits are never of large extent. They are usually pockety. The ore comes in lenticular shoots, and masses in

[1] From Bulletin 652. Tungsten Minerals and Deposits, U. S. Geological Survey.

veins or irregularly distributed along contacts. When a new district is first discovered a great deal of float ore may often be found. Later the surface ore is gophered out. Up to this stage the tungsten ore is easily and quickly mined, and the production is large and low costs prevail. Then follows the period of searching for ore underground. This is a different problem. The geology of tungsten deposits is not well understood. Underground prospecting is difficult. The "leads" are hard to follow, and, almost invariably, a large amount of deadwork needs to be done before a new shoot is found. After drifting along a narrow vein or crosscutting through barren rock, it often happens that even if more ore is discovered, its value is insufficient to pay, in addition to the cost of its extraction, the heavy cost of looking for it. This is the period of depression. Temporary excitement or a "boom" like that which swept over Colorado and the whole world in 1916 when the price soared to record heights, may bring about a greater production, but this is mostly obtained from extremely low-grade material and at high cost. Very few, if any, districts have emerged from the stages of unprofitable underground prospecting and development to the establishment of a permanent, profitable producing stage. Tungsten has the reputation of "playing out" at depth. The character of the ore is such as to preclude this possibility and tungsten is no more likely to pinch out vertically than horizontally, but as the depth increases the pockets are harder and more expensive to find.

USES.

At least 95 per cent of all the tungsten ores produced at the present time go into the manufacture of tungsten powder, ferrotungsten, and tungsten steel for the making of high-speed tool steels. The addition of tungsten to steel gives it the property of holding its temper at a much higher heat than that at which simple carbon steels, and most other alloy steels, become soft and worthless. This property of red hardness, as it is called, is very important in cutting tools, as it allows speeding up the work to five or six times the cutting speed allowable with simple carbon steel tools. The strength and comparative toughness of tungsten-steel lathe tools, even when very hot permits taking a very heavy cut or shaving off the work and the chips often leave the tool so hot that they turn blue. The rapid advance in cutting metals and the great increase in efficiency in machine shops in late years is in a large measure due to the development of tungsten tool steel.

A new use for tungsten steel is for aeroplane engine valves and seats. For several years tungsten steel has been the most satisfactory material for the permanent magnetos (used for telephones and internal combustion engine ignition).

An important use of tungsten ores, though one that consumes but a negligible amount, is the making of pure tungsten wire for incandescent lamp filaments. A little tungsten goes into electric contact points for spark coils, etc. (as a substitute for platinum).

Steel containing 2 or 3 per cent of tungsten is in general use for saw blades.

Formerly sodium tungstate and other tungsten-containing chemicals were used to some extent in weighting silk, mordanting, and other purposes but this consumption has practically ceased on account of the high cost of tungsten.

SUBSTITUTES.

No satisfactory substitute for tungsten has been found for alloying with steel for high-speed cutting tools. Molybdenum has somewhat similar properties, and although it has been used to some extent, especially in Europe, it has never proved so satisfactory and is now generally used in conjunction with tungsten, replacing only a part of the latter. Stellite, an alloy of cobalt and chromium, is sometimes used for cutting tools as a substitute for high-speed steel. The most satisfactory stellite alloy for cutting, however, contains tungsten as a hardening constituent, although molybdenum is also employed instead of the tungsten in this alloy.

The high prices of 1916 stimulated conservation of tungsten, and most cutting tools are now made with an ordinary carbon steel stock with only a short piece of high-priced tungsten steel welded on the end. This practice results in a marked saving in the metal and was a large factor in breaking the price.

Chromium as well as molybdenum has to some extent replaced tungsten in the making of magnet steel.[1]

MINING METHODS.

Placer tungsten may be worked by any of the usual methods for the recovery of gold or tin in placer deposits. Except when associated with tin or gold, tungsten is not known to be mined by dredging, as the deposits are rarely of sufficient extent to warrant the cost of erecting so expensive a device. Hand washing in pans or sluices is the usual procedure, but in large-scale operations, hydraulicking is done.

Lode mining does not differ essentially from the mining of other ores except that tungsten rarely is found in sufficient amounts or in shoots regular enough to permit of systematic extraction. As a rule the valuable material forms a narrow, tight streak in the rock. These streaks are usually only a few inches wide; and as a man can not work for any length of time in a space less than 18 to 24 inches wide, much barren waste must be broken separately to make room. Care must be taken to prevent the mixing of this rock with the ore. This is often difficult as the tungsten stringers are "frozen" tight to the walls and, although hard, are easily fractured and lost. To further complicate the extraction of tungsten, the country rock and vein formation are usually very hard. It is evident that these conditions require a peculiar type of miner and one who has a personal interest in saving every possible particle of valuable material. This necessity fosters the employment of "leasers" (lessees) or "tributers"—each man, or group of men, working for himself and being paid for the ore he gets out—rather than the usual system of day's pay.

[1] See Tariff Information Catalogue on Ferrotungsten.

CONCENTRATION OR MILLING.

The tendency of all tungsten minerals to slime, coupled with the necessity of very fine grinding to separate them from the waste rock, complicates their economical recovery in the milling operation. Stamps were formerly in common use for the secondary crushing after the breaker, but these relics of gold milling are notorious producers of slime and material too fine to be recovered effectually by any mechanical process. Stamps have, therefore, disappeared from most of the mills and have been replaced by several sets of rolls which successively reduce the size of the ore with a minimum of sliming. Only a small proportion of tungsten concentrate is recovered by jigging the coarse sizes. The bulk of the recovery is on the sand and slime tables. The last slime is still run through a "rag plant" (canvas tables) at many mills with an economical saving.

The desideratum of concentration is the production of a concentrate containing 60 per cent or more tungsten-trioxide, but the production of so high grade a product from the usual ore containing only 2 to 10 per cent WO_3, results in high losses and much waste of tungsten. To increase the extraction, many mills make two grades of concentrate; a high grade sand concentrate, containing approximately 60 per cent WO_3 and suitable for making ferrotungsten in the electric furnace; and a slime concentrate of lower grade, containing about 20 per cent WO_3, and suitable only for a chemical process.

If any heavy minerals besides tungsten are present in the ore, the enriched product from simple gravity concentration contains these other minerals also and they must be removed, either because they lower the grade too much or because they are actually deleterious to the product. The usual auxiliary process is magnetic separation and the method of its application depends on the character of the material. Many foreign ores contain tin as well as sulphide minerals. In the United States the chief contaminants of the concentrate are sulphides. Iron sulphide can be easily removed by a weak magnet after a light roast. Ferberite and even wolframite are slightly magnetic and can be picked out by a strong magnet, leaving nonmagnetic sulphides and tin as a separate and, frequently, a salable product.

There has been marked progress in the milling of tungsten ores in the last few years, but it is still a by no means easy problem to get a satisfactory recovery of the minerals in a sufficiently high grade product. Extractions of over 80 per cent are reported, but it is doubtful if the average mill recovers 70 per cent of the values, and this on ore that is fairly high grade as compared to ores of other metals. It is not practicable to treat any material with less than 1 per cent of tungsten oxide, and in most districts ore with less than 2 per cent is not worth treating. Ore containing 1 per cent of WO_3 may have a theoretical value of over $20 a ton, but it is seldom profitable to mill it even when it has been mined and on the dump, whereas ores of gold, copper, or lead with a theoretical value of only $2 or less per ton are profitably concentrated. The reason is the high cost of the separation. A relatively expensive plant is required and the ore must be put through slowly—often rerun—in order to get a fair recovery.

Chemical concentration is rarely resorted to because it is even more expensive than the mechanical processes. Its main field is in the

separation of foreign ores containing tin and other impurities and in the treatment of low-grade slime concentrate. The usual method [1] is to decompose the material by fusing it with soda ash, forming sodium tungstate, which can be leached out with hot water. In the case of siliceous ores the consumption of soda is prohibitive, but it is possible to leave tin and most of the other metal oxides practically unattacked. The solution containing the sodium tungstate is treated with muriatic (hydrochloric) acid which precipitates tungstic acid (H_2WO_4). The tungstic acid, after ignition to the anhydride (or tungsten trioxide, WO_3), can be reduced to metal powder by means of coal or in a stream of hydrogen.

COUNTRIES OF LARGEST PRODUCTION.

Tungsten ore is widely distributed and is found in all the continents of the world and in a great number of countries; but no single country produces a very great amount and the resources of almost every corner of the globe are drawn on to furnish a supply. Burma (and the Shan States) is the largest individual producer, and in 1917 mined 21.4 per cent of the total world output. The United States was the next largest producer, furnishing 17.1 per cent, while Bolivia was a close third with a production amounting to about 15.8 per cent of the world's total. These three large producers, therefore, accounted for only a little more than one-half of the production; the remainder was drawn in small amounts from many other countries—especially in Asia. In the same year Asiatic countries produced 41.8 per cent of the world's output; South American countries, 22.2; North American countries, 18.4 per cent; European countries, 11.3 per cent, and Australia and New Zealand, 6.3 per cent. Africa is the only continent that does not make an important contribution to the tungsten supply. Even Africa, however, reports an annual output.

The following table shows the world's production, the United States production, and the percentage of the world's total produced by the United States:

Concentrates 60 per cent WO_3.

Year.	World's production.	United States production.	Per cent produced by United States.
	Short tons.	*Short tons.*	
1910	7,570	1,821	24.06
1911	7,517	1,139	15.15
1912	9,654	1,330	13.78
1913	8,476	1,537	18.13
1914	7,877	990	12.57
1915	12,328	2,332	18.92
1916	23,671	5,900	24.92
1917	27,067	4,633	17.12

[1] Another commercial chemical method is outlined in the confidential files of the commission.

The world's production of tungsten ore, by countries, estimated so far as possible in short tons of concentrates containing 60 per cent of tungsten trioxide.

Country.	Year.					Year.			
	1910	1911	1912	1913	1914	1915	1916	1917	[1]1918
	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.
Africa: South Africa	(1)	(1)	(1)	(1)	(1)	1	2	[2] 5	25
Asia									20,310
Burma and Shan States	407	1,119	2,095	1,905	2,055	3,010	4,637	[2]5,800	.....
China							120	[2]1,500	.....
Federated Malay States	105	205	275	273	317	363	552	795	.....
French Indo-China (Tonkin)	19	.....	81	100	119	219	250	250	.....
India (not including Burma)	23	.....	.....	(1)	(1)	(1)	[1] 100	[2] 100	.....
Japan	275	287	225	327	226	478	771	[2] 775	.....
Korea (Chosen)	.....	.....	.....	.....	.....	.....	750	993	.....
Johore and Kedah	.....	.....	.....	.....	.....	.....	48	[2] 50	.....
Siam	.....	200	200	1	33	475	584	660	.....
Trengganu (Malay Peninsula)	.....	.....	.....	.....	173	175	329	[2] 350	.....
Australia									1,150
New South Wales	413	512	298	220	244	109	345	[2] 300	.....
Northern Territory	78	71	44	42	50	50	45	[2] 50	.....
Queensland	1,145	750	944	587	442	708	503	519	.....
Tasmania	75	86	87	89	61	150	[2] 124	292	.....
Victoria	31	33	13	1	(1)	(1)	1	(1)	.....
Western Australia	2	12	(1)	1	1	(1)	(1)	(1)	.....
South Australia	.....	.....	.....	.....	.....	.....	1	(1)	.....
East Indies:									
Billiton	21	.....	21	20	20	20	20	60	.....
Singkep	12	.....	8	10	10	10	10	.....	.....
Europe									3,000
Austria	54	50	73	75	75	75	[2] 150	[2] 150	.....
England	307	298	216	204	230	399	464	.....	.....
France	33	188	252	300	300	200	182	[2] 182	.....
German Empire (Saxony)	105	80	111	150	150	150	350	[2] 200	.....
Portugal	1,132	1,078	1,466	900	1,000	1,038	1,563	1,741	.....
Spain	169	106	202	179	175	211	187	360	.....
Italy	.....	.....	.....	.....	.....	.....	6	6	.....
Oceania, New Zealand	187	184	181	297	274	261	446	[2] 550	400
North America:									
Mexico	.....	.....	.....	.....	.....	155	175	341	326
Nova Scotia	83	(1)	17	12	(1)	(1)	(1)	.....	.....
United States	1,821	1,139	1,330	1,537	990	2,332	5,900	4,633	5,046
South America									6,300
Argentina	826	683	702	591	482	189	908	1,000	.....
Bolivia	232	370	547	328	320	902	3,624	4,229	.....
Brazil	.....	.....	.....	.....	.....	.....	6	.....	.....
Chile	.....	.....	.....	.....	.....	.....	9	[2] 10	.....
Peru	15	57	241	327	130	455	586	[2] 700	.....
Total	7,570	7,517	9,629	8,476	7,877	12,225	23,671	27,067	36,557

[1] No tungsten ore produced so far as can be learned. Figures in the above table were derived from various sources published by the U. S. Geological Survey, in Mineral Resources.
[2] Estimated.

DOMESTIC PRODUCTION AND RESOURCES.

Colorado was the chief tungsten producer of the United States for 14 years. In 1914, the production of California was greater than that of Colorado. In 1916 and again in 1917, their respective productions were practically equal and their combined output is about 90 per cent of the total output of the country. Nevada is the third largest producing State, but its output is considerably less than that of either of the first two. Arizona is a small but regular producer. South Dakota has been an intermittent producer of wolframite, which is found in association with the gold ore of the Black Hills. Tungsten ore has also been produced in New Mexico (wolframite), Utah (scheelite), Idaho (huebnerite), Missouri, and Connecticut, and showings have been reported in other States.

PRODUCTION IN UNITED STATES.

Tungsten-bearing ores (concentrates containing 60 per cent WO_3).

[Figures from Mineral Resources, United States Geological Survey.]

States.	1910		1911		1912	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Arizona	(1)	(1)	45	$16,559	24	$9,566
California	(1)	(1)	(1)	(1)	(1)	(1)
Colorado	1,090	$535,567	652	234,513	725	297,533
Idaho	.....	.....	(1)	(1)	(1)	(1)
Nevada	.....	.....	(1)	(1)	(1)	(1)
New Mexico	.....	.....	.....	.....	.....	.....
South Dakota	268	64	.....	.....	.....	.....
Washington	92	51,768	(1)	(1)	.....	.....
Alaska	.....	.....	.....	.....	.....	.....
Connecticut	.....	.....	.....	.....	.....	.....
Utah	.....	.....	.....	.....	.....	.....
All other	176	245,593	320	156,913	438	195,059
Total	1,626	832,992	1,017	407,985	1,187	502,158

States or cities.	1913		1914		1915	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
Arizona	14	$6,069	13	$6,435	113	$245,360
California	483	226,260	(1)	(1)	859	1,005,467
Colorado	851	428,760	417	182,013	860	2,311,200
Idaho	(1)	(1)	(1)	(1)	29	47,602
Nevada	(1)	(1)	.....	.....	49	130,466
New Mexico	(1)	(1)	(1)	(1)	40	70,934
South Dakota	(1)	(1)	.....	.....	125	181,089
Washington	(1)	(1)	.....	.....	(1)	(1)
Alaska	.....	.....	.....	.....	(1)	(1)
Connecticut	.....	.....	.....	.....	(1)	(1)
Utah	.....	.....	(1)	(1)	(1)	(1)
All other	24	11,029	454	246,552	7	107,882
Total	1,372	672,118	884	435,000	2,082	4,100,000

States or cities.	1916		1917		1918	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).[2]	Value.
Alaska	41	.....	25	.....	25	.....
Arizona	195	.....	156	.....	190	.....
California	1,912	.....	1,951	.....	1,590	.....
Colorado	2,108	.....	1,893	.....	1,705	.....
Connecticut	3	.....	.....	.....	.....	.....
Idaho	90	.....	4	.....	.....	.....
Montana	1	.....	.....	.....	20	.....
Missouri	4	.....	.....	.....	.....	.....
Nevada	615	.....	.....	.....	790	.....
New Mexico	14	.....	.....	.....	.....	.....
Oregon	1	.....	.....	.....	.....	.....
South Dakota	213	.....	.....	.....	[3] 185	.....
Utah	36	.....	.....	.....	.....	.....
Washington	10	.....	.....	.....	.....	.....
All other	.....	.....	108	.....	.....	.....
Total	[4] 5,243	.....	[2] 4,137	.....	4,505	.....

[1] Included in "All other."
[2] Subject to revision.
[3] Includes Utah.
[4] Later figures (subject to revision) show 5,268 long tons in 1916.

Colorado.—Practically all the Colorado output is mined in Boulder County. The tungsten is found in a belt nearly 12 miles long and about 7 miles wide, situated about 25 miles northwest from Denver and centering about Nederland. Prior to 1914 this district produced fully 60 per cent of the tungsten output of the United States, 75 to 80 per cent of which came from shallow workings that are now exhausted.

The dominant ore is ferberite, which is not mined to any extent in any other part of the world. It is typically difficult to mine, as it is usually found in very narrow seams or comparatively small lenses in very hard granite or gneiss. The absence of tinstone, tourmaline, and other common associates of tungsten minerals is noteworthy. The Boulder County ore is exceptionally free from impurities and generally commands a higher price than foreign ores because of its extreme purity. The average grade of the ore in Boulder County is perhaps 5 per cent WO_3,[1] and the dump ore at producing mines will contain about 0.5 per cent. It is significant that the great excitement of 1915–16 failed to open up any important new ore bodies in this district. Practically all the large areas of float ore and the easily mined surface deposits are exhausted, and now the production comes almost wholly from fairly deep workings, which are more expensive to mine. The ore shoots are variable in length and depth. The average thickness of the mineral bearing vein matter is only a few inches.

In 1916 there were 10 concentrating mills operating in the district, but in 1918 fully half of them were shut down. Only the larger companies have survived. A large proportion of the producing properties are owned and operated by consumers of tungsten, i. e., steel companies or manufacturers of ferrotungsten and other tungsten products. Mining and development are done almost exclusively under the leasing system, the "leaser" being paid for the ore he extracts (after deducting a royalty). When an unusual amount of prospecting or "dead" work is necessary, the expense is either shared by the company and the lessee or done on "company account."

Tungsten ore has been mined at various other localities in Colorado, notably in the southern section, where huebnerite is the chief ore. The production has never been important, and practically all these mines ceased operations in 1917 or earlier.

California.—California is the largest producer of scheelite in the world. The greatest proved bodies of tungsten ore in the United States, and perhaps in the entire world, are those of the Atolia-Rand district in San Bernardino County in the southwesterly section of this State. The Atolia deposit has been worked to a depth of 700 feet, vertical, and the width has in many places exceeded three feet of tungsten bearing material, consisting largely of scheelite and quartz. Like the Colorado ore, the California product is exceptionally free from harmful impurities. Since the adverse prejudice of consumers has been overcome, the California scheelite has commanded a premium over imported ores and even over the Boulder County concentrate which is more difficult to reduce.

[1] Brief of Tungsten Producers, Tariff Commission, Denver Conference.

The deposits are found along more or less continuous fissures and may be broadly classed as contact metamorphic deposits in distinction from the stringer lodes of Colorado. The deposits, therefore, are often of much larger extent, although frequently low grade. The same geological formation found at Atolia extends east and west. Westward, the ore in Kern county is wholly scheelite. Eastward, more or less of the wolframite series of tungsten minerals is found along with the lime tungstate. Scheelite is the principal tungsten mineral so far produced in California and the wolframite deposits, especially those dominantly of huebnerite, have been generally low grade and pockety. There is no ferberite, but there are two districts in San Bernardino county where the ore is characteristically wolframite.

There are four counties in this State from which tungsten has come, San Bernardino, Inyo, Kern, and Nevada. By far the largest production has been derived from San Bernardino and the major part of this has come from the Atolia Mining Co. which began producing in 1908 and has maintained active mining ever since. One of the most interesting developments in the last few years has been that in Inyo county, where the ores differ from the more distinctly lode occurrences of other sections, as the scheelite is disseminated through metamorphic rock. The ore bodies are much larger than even the big Atolia deposit but the average grade of the ore treated is less than one per cent (occasionally as low as 0.5 per cent) whereas the ore of the Atolia Co. runs from two to eight per cent WO_3 in the mill dirt and some high grade is obtained by sorting. There are four mills operating in Inyo county (1918). The production from Kern county and from the balance of the Atolia district, outside of the Atolia Mining Co., comes largely from small operators who produce a few tons here and there, partly from lodes and partly from placer workings. "It appears, however, that there are large bodies of low-grade ore from which economical recovery could be made if the price was a sufficient inducement."[1] A small amount of scheelite has been produced in Nevada county, over 300 miles from Atolia.

Nevada.—The only important production so far made by Nevada was in 1916 when 615 tons of 60 per cent concentrate were produced. The most extensive production has come from White Pine County and from Sodaville in Humboldt County. The ore is largely scheelite. During the period of high prices (1915–16) these counties were very active but nearly all operations were discontinued soon after the spectacular decline in the tungsten market. Extraordinary finds of large bodies of high-grade ore have been reported from time to time, in various parts of the State, but the sudden cessation of output coincident with the break in price raises some question as to the accuracy of the statements. The evidence submitted at the United States Tariff Commission conference in San Francisco, especially the statements of Messrs. Ackerman and Bradley, indicates a strong probability of the existence of important bodies of low grade ore, particularly in Nye and Mineral Counties. In these counties, no lode deposits have been exploited, but a very large tonnage of placer material is said to be available. There is a large ore-body at Bishop, Inyo County, that is believed will eventually furnish a large supply

[1] W. W. Bradley (representing Fletcher Hamilton, State mineralogist of California), United States Tariff Commission San Francisco Conference Report, p. 57.

of tungsten at a very low cost. The development of the low grade deposits of Nevada will require a considerable outlay of capital. The tungsten area can be broadly considered as a continuation of the California formations, which it resembles in many particulars. There is a larger proportion of wolframite, especially huebnerite, but scheelite is the dominant tungsten mineral. Many of the deposits also contain sulphide minerals, but a good grade of concentrate can be made as there are few very objectionable impurities.

Alaska.—Although scheelite had been known to exist in several of the Alaskan placers, the demand was insufficient to encourage its recovery until 1915 The production has never exceeded 50 tons a year and this is mainly a by-product of the gold-dredging operations in the Nome placers. There is a small lode production in the Fairbanks district.

FOREIGN PRODUCTION AND RESOURCES.

Burma.—Burma, including the Shan States, has been the largest producer of tungsten in the world since 1912. It is one of the newest tungsten producing areas. The first important output was made in 1910.

There are four important districts found in a belt about 56 miles long and 7 miles wide and at least 50 producing mines. The ore is wolframite and the output has come largely from placers and surface float. Ground sluicing is the common method of recovering the valuable mineral, but hydraulicking is employed at some of the larger properties and lode mining is on the increase. The most important lode district is Tavoy, where the veins are found in a schist of sedimentary origin, capping granite. No lowering in grade has been reported as the veins extend downward into the granite; but the width is generally less—a vein 2.5 feet wide in the schist, narrowing down to 2 feet or less in the granite. All the tungsten deposits contain tin, which is frequently an important by-product. Other harmful impurities, such as galena, pyrite, columbite, and molybdenite, are also invariably present.

The Burmese tungsten industry passed from German to British control in 1915. All shipments had formerly been made to Hamburg and the assays made by the German Government for the duty assessment (2.5 per cent ad valorem)[1] were accepted by buyers and sellers as the basis of settlement. The outbreak of the war resulted in a temporary derangement of the tungsten industry in this area, and in spite of the urgent need of the British Government for tungsten, Burma did not respond rapidly at first. Prospecting is hindered by heavy rainfall in the summer months, amounting to 200 inches from May to November. Lack of transportation and title difficulties were serious handicaps in addition to a shortage of labor. The British Government took an active part in the mining and marketing of Burmese tungsten in the fall of 1915. The government imported coolies and managers to work the mines and claims that were lying practically idle, and built roads and bridges. Under this stimulus, production increased 50 per cent in 1915 and the output in

[1] Mineral Industry, XXIII (1914), p. 754. Probably a countervailing tariff as tungsten ore is normally admitted free into Germany under the act of 1906.

1917 was almost three times as great as in 1914. There was some protest from mine owners because of the importation of 1,500 coolies that had no mining experience and had been promised high wages (comparatively); but the main contention was the fixing of the maximum price of 55s. ($13.365) per long ton unit (22.4 pounds) of WO_3 when prices in neutral countries were several times as much. That this price did not allow sufficient profit is evidenced by the fact that it was later (1917) increased to 60s. ($14.60) a long ton unit (These quotations were for 65 per cent concentrate, f. o. b. Liverpool.)

The labor in Burma is almost wholly Chinese under the direction of white superintendents. Mining and development are usually under contract. In spite of the large increase in the output, the methods of mining are still primitive. Most of the crushing is done by hand hammers and the ore is concentrated in cradles (by hand). There is seldom any attempt to remove tin at the mine. Some of the ore is treated with magnetic separators to take out the tin before shipping to England, but usually the mixed product is shipped. One or more magnetic separators have recently been installed at Rangoon.

Other Asiatic countries.—Nearly all the tin mines of the Malay Peninsula produce more or less tungsten as a by-product. Smaller amounts are mined in French Indo-China (Tonkin) and in Siam. Most of the ore is wolframite, although some scheelite is found. The Siamese area is a continuation of the Burmese and the ore is found on surface. Laborers are paid not over 50 cents (gold) a day. The cost of production is very low, the chief expense is the government tax (30 to 40 per cent) and the cost of bags which is very high in that country. Permits for export were subject to the control of the British legation at Bangkok and were practically impossible to get in 1918. The ore cost $15 to $17 a unit, c. i. f. American ports.[1]

A new and probably important production comes from southern China in the Provinces of Hunan and Kwantung. The production in 1917 was more than 100 tons a month. The work was done entirely by hand, most of the ore being merely picked up off the ground. The product had to be carried on men's backs or little river junks to Canton, whence it was shipped to Hongkong. It came under British control at Hongkong and permits to ship to the United States were not granted in 1917.

The total output of Japan and Korea (Chosen) in 1917 was practically 1,770 tons (on the basis of 60 per cent concentrate), nearly 1,000 tons of which came from the latter country. Korea is likely to become a more important producer as soon as the war-time embargoes on shipments are removed as much high-grade ore is reported from various sections and great bodies of low-grade complex ore have been proved up.

Australia.—Tungsten ore has been mined in all the territories of Australia. Queensland is the largest producer and New South Wales, second. Australia was for several years the largest producer of tungsten ores in the world, but when the surface ores were exhausted, mining languished, the output dwindled, and the United States took the premier position (1906–7). Both wolframite and scheelite are found in nearly all the districts. The tungsten is generally associated with molybdenite and bismuth and is rarely found in well-defined

[1] O. Nassauer, Tariff Commission Conference Reports, p. 153 (San Francisco).

lodes. The shoots are typically erratic and hard to find. The bulk of the output comes from placer deposits of scheelite. The only possible checks to the waning output of Australia are the development of lode mining and the solution of certain metallurgical problems connected with the separation of the complex scheelite ores. Every effort was made to increase the production since the outbreak of the war, but unsuccessfully (up to the end of 1917).

Portugal.—Portugal has maintained its position as the chief tungsten producing country in Europe for many years. Tungsten is found in widely separated regions in Tras Os Montes and Beira Alta (in the northerly and central sections of the country) and occurs in quartz veins, of the fissure type, cutting both granite and Archaean schists. There are no deep mines, mining having stopped at or near water level. The ore is generally associated with lead, zinc, or iron sulphides in the veins and is mostly wolframite and huebnerite, though some scheelite is found. Tin and titanium are found in the country rock with no evidence of vein formation and are concentratedwith the tungsten ores in alluvial deposits. The latter are an important source of tungsten. Most of the production an 1914 was by British-controlled companies, but French interests were extended after the outbreak of the war, and in 1916, American capital acquired important holdings. By an agreement with the Portuguese Government the products of the mines are shipped to England, France, and the United States, respectively. The remainder of the production, from locally controlled mines, is purchased by agents of the three foreign companies. In 1917 the average cost of production of five properties operated by hand methods was $8.22 per long ton unit plus $1.07 Government tax and $0.50 freight. The average cost at three plants, one British and two American, operated by mechanical methods was $7.59 plus the same charges.[1] The ore was sold at the British Government fixed price of 55s.[2]

Portugal produced the equivalent of 1,741 tons of 60 per cent concentrate in 1917. This was 57 per cent of the whole European production. Most of the product is comparatively free from tin, sulphur, bismuth, and phosphorus.[3]

Other European countries.—Tungsten ore, chiefly wolframite, is produced in Spain, Cornwall, France, Germany, and Austria-Hungary. The average annual output of each of these countries is approximately 200 tons. The productions decrease slightly in the order named. Russia produced 110 tons in 1917 and this was practically its first production. A few tons are mined in Norway and Italy every year. Most of the European tungsten deposits are associated with tin mines, and the ores are generally contaminated with tin and other harmful impurities.

South America.—Wolframite, scheelite, and huebnerite are all found along the eastern cordillera in Bolivia, Argentina, and Peru and in Chile and Brazil. In 1917 Bolivia produced over 70 per cent of the whole South American output, and its production was almost as great as that of the United States, or the third largest in the world.

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[1] F. W. Foote and R. S. Ransome, jr., Eng. Mg. Jl. 106 (1918), pp. 47–53.

[2] Ibid. p. 50. The authors estimate the net value at $11.80 a long ton unit after deducting freight to England, insurance, etc. This leaves a profit margin of $2.64 a unit to the plants with mechanical equipment and $2.01 a unit to the plants working by hand methods.

[3] A discussion of mine labor conditions in Portugal will be found in the miscellaneous section.

The Bolivian ores are found at high altitudes, between 13,500 and 16,500 feet above sea level. Only natives, accustomed to work at such altitudes, can do any physical work at these elevations; the labor supply is, therefore, limited. Transportation is difficult and the ore must be sent down aerial tramways to a place where water can be had for concentration. Silver is a common associate of the tungsten and is usually present in sufficient value to warrant a preliminary leaching of the ore with hyposulphite of lime to extract the precious metal before the mechanical concentration for the recovery of the tungsten. As the tungsten veins are often crossed and intertwined with tin veins, the mining of the two metals goes hand in hand, and the concentration of the mixed ore involves this difficult separation (which is rarely complete). Copper is another unwelcome associate and there is generally some bismuth.

About 70 per cent of the Bolivian output comes from the Department of Oruro, 20 per cent from La Paz, and the remainder from Potosi. Approximately 75 per cent of the production is exported to the United States, most of the remainder to England, in 1917; but in that year there was much competitive buying by French and British commissions, and in 1918 a larger part of the ore was diverted to Europe.

Argentina is the second largest of the South American producers. Tungsten and petroleum are practically its only mineral products. The chief production has come from a mine in the Sierra Cordoba, controlled by the Hansa Sociedad de Minas, a German concern.[1] The Argentine ore was all shipped to Germany before the war and in 1915 operations were temporarily suspended. Later the output was contracted for by American firms and production resumed and increased. In 1917–18 there were large shipments to Europe as well as to the United States.

Most of the Peruvian mines are owned and operated by native capital. The tungsten minerals are huebnerite and wolframite and are generally accompanied by considerable, even economical, amounts of copper. As in most Andean mines, development and operation are hindered by the extreme difficulty of transportation. Only a few mills have been erected and most of the concentrating is done by women who hand pick the coarse material and pan the fines. In 1916–17 English interests secured an option on the Huara deposits in the Province of Ancachs. These are reported to be the largest bodies of tungsten ore in the world.[2]

In common with most mineral products, tungsten ore exports from nearly all South American countries are subject to an export tax, which is generally based on a sliding scale depending on the price of the ore as well as the financial necessities of the individual country. These taxes are constantly fluctuating.

Canada.—No important discoveries of tungsten minerals have been made in Canada. A small and fairly steady output of scheelite has been maintained in Nova Scotia, largely as a by-product of the treatment of gold ore. Tungsten finds, and a sporadic production, have been reported from British Columbia, New Brunswick, and Ontario.

[1] Mineral Industry, XXIII (1914), p. 750. A characteristic feature of the Cordoba ore is the presence of appreciable amounts of the very rare metal niobium, some specimens run as high as 1.5 per cent niobium oxide (Nb_2O_3).

[2] Min. Jour., Mar. 3, 1917.

Mexico.—Since 1915 small shipments of tungsten have been made from various parts of Mexico, especially Sonora. Much of it has been marketed at a comparatively low price, being stolen ore or ore mined by "high-graders." It is handled at Douglas, Ariz., by American ore buyers. Scheelite is a minor constituent of the Moctezuma Copper Co. (Phelps-Dodge) ore at Pilares de Nacozari, but so far as known, no attempts have been made to recover it.

COSTS.

Any accurate estimate of the average cost of producing tungsten ore is impossible. The main difficulty is to determine the cost of developing the ore body. This may be either very great or very small. In surface workings, the element of prospecting is often practically negligible and the total cost of production is only slightly more than the working cost. In deeper mines, the cost of dead work and drifting in search of new bodies is a large item. Under the leasing system, especially, the determination of this cost is impossible, since one lessee after another will do some work on the same block of ground and then quit. Most of the production throughout the world comes from small operators that seldom keep any accurate records. Even when accurate records are kept, the costs are so widely different that any attempt to correlate them is fruitless.

The main factor in all mining costs is the cost of labor, and wages have risen all over the world. Supply costs have also increased. In the tungsten industry, costs have increased from 40 to 50 per cent during the war period. Considerable data in regard to costs in 1912–13 were given in tariff hearings and are summarized on page 15.

Detailed cost figures have been furnished by a number of domestic producers. These are available in the confidential files of this commission together with the data furnished at the conferences held at Denver and San Francisco. In Colorado the costs in 1918 of the larger producers were estimated to run from $15 to $33 per unit, with an average cost of approximately $20. Californian costs are lower, but it is doubtful if any large production in that section can be maintained at a cost of less than $10 per unit, with much of it costing considerably more. Before the war, the Atolia Co. sold ore at less than $6 per unit, but the production came then from the upper levels of the ore body; the vein in those horizons was richer and wider, and operating costs have increased very rapidly during the war period.

While the available data are not wholly satisfactory, it seems probable that only about one-half of the domestic output is produced at a cost of from $10 to $15 per unit, and that the remainder costs from $15 to $25 per unit, averaging, say, $20. It is very unlikely that any considerable amount of tungsten ore can again be produced at much, if any, less than $10 per unit unless large, low-grade deposits can be systematically developed and equipped for production on a large tonnage basis.

Foreign costs are much more difficult to ascertain. A large range of estimates has been secured from various sources. Many of these estimates run considerably above the prices that the British Government was paying to producers during the war period and are manifestly too high. On the other hand, it is stated that much of the

Burmese ore is produced for less than $2 per unit. There is little uniformity in the figures and no definite conclusions can be drawn from such data. A better index is the record of sales in the consuming markets. As soon as shipping restrictions were removed after the signing of the armistice a flood of tungsten ore came to the United States from China and the Far East. This material was sold as low as $6 per unit on the New York market and most of it changed hands at much less than $8 per unit. Undoubtedly some of these sales represent liquidation of stocks with slight regard to profits. A little of it may even have been sold below the delivered cost. But it is significant that nearly seven months after the embargoes were removed this ore is offered at $7 per unit in New York, although quotations on future deliveries from China are placed at $8. Apparently a large supply of Chinese ore can be placed on the New York market at less than $10 per unit, until these bonanza deposits of improved extent are exhausted (unless, of course, the cost to the importer is increased by a duty placed upon the ore).

Costs in other Far Eastern countries—Bolivia and Portugal—must also be judged by the prices at which their product is sold in consuming markets. On this basis they come between the very cheap Chinese (and Burmese) material and the more expensive production of the United States. The British Government controlled prices on tungsten ore—drawn from Burma, Portugal, and Bolivia—have ranged from $13 in 1918 to $6.25 in early 1919.

MARKETS AND MARKETING.

In the prewar period Germany was the clearing house for most of the tungsten ore mined in the world, and a large part of the tungsten powder and ferroalloy was manufactured in that country and furnished to steel makers throughout the world. Most of the American production, however, has always found a ready market at home and was reduced in the United States. The world situation was abruptly changed by the outbreak of the war and the elimination of the Central Powers from general commerce. Great Britain controlled more than half of the tungsten output of the world, so that country now became the logical center of the industry. The construction of reduction plants was started at once and these were soon able to take double the amount of ore readily obtainable. The steadily growing demands of American steel makers, which far exceeded the domestic production of ore, resulted in active competition between British and American interests for South American and Asiatic ore, and even for the Portuguese output. In an attempt to straighten out this tangle of interests, a contract was drafted in 1917–18 whereby each country should retain control of all tungsten produced in its own territory, while that produced in other countries was to be equally divided between the two contractors. In view of the fact that fully two-thirds of all the tungsten output of the world was produced in British-controlled territory, this agreement would have been manifestly disadvantageous to the American industry, whose requirements exceeded those of the British steel makers, and it was never consummated.

The chief market for tungsten ore in the United States is in the Eastern States, especially in the vicinity of Pittsburgh. Only a small part of the total domestic concentrate is reduced in Western States

closer to the mines, so most of the concentrate must be shipped East. In stringent markets it sometimes goes by express.

Many tungsten concentrates contain deleterious impurities which impair their value as sources of ferrotungsten. Most metallic impurities are reduced along with the tungsten in the electric furnace if not removed beforehand, and hence would go into the steel and injure its quality. Objectionable impurities are antimony, arsenic, bismuth, copper, lead, nickel, tin, zinc, phosphorus, and sulphur. Fortunately for the American producer, domestic ores are singularly free from the more objectionable impurities. Most foreign ores contain them in more or less amounts, and, consequently, almost invariably sell at a discount.

The usual quotations for tungsten ore are based on material containing 60 per cent tungsten trioxide and no objectionable impurities.[1] Separate quotations are sometimes published for wolframite and scheelite. The latter is more easily reduced in the electric furnace and commonly valued $1 or more a unit higher than wolframite. A slightly better price can be gotten for ferberite than for wolframite, while huebnerite sells for a little less than the standard ore. The removal of a large manganese content in the electric furnace is difficult and since it tends to lower the grade of the ferroalloy, it is undesirable.

The above statements apply to ores of the same tungsten content. A reduction in WO_3 content below 60 per cent is penalized and a product containing less than about 40 per cent WO_3 is bargained for with little reference to published quotations, even though it may contain no harmful impurities.

Mine dirt up to 20 or 30 per cent WO_3 can be sold only to custom concentrating mills. The price paid is a matter of agreement between the producer and the millman. A sliding scale is usually adopted. In Boulder County, Colo., one mill [2] bases its payments on the published New York schedule with liberal discounts to cover losses, cost of treatment, and market uncertainties. The following example is illustrative: Engineering and Mining Journal quotation, $22 a unit for 60 per cent WO_3; mill quotation, $18 on 60 per cent. The price paid per unit for 2 per cent ore is $5 a unit (i. e. $10 a ton), and this price per unit is increased by $1 a unit for each 1 per cent increase in grade of the ore up to 7 per cent (which is, therefore, valued at $10 a unit or $70 a ton). From 7 to 18 per cent WO_3 the price per unit is increased only 15 cents a unit for each 1 per cent improvement in grade.

DOMESTIC PRODUCTION AND PRICES.

The question of prices is more intimately interrelated with that of production in the tungsten industry than in any other branch of mining. The following table illustrates the growth of the industry in the United States and its extraordinary expansion under the stimulus of high prices, in spite of the depletion of easily mined deposits and surface ore:

[1] Foote Mineral Co. specifications for commercial grade, guaranteed: Tungsten trioxide, minimum, 60 per cent; sulphur, copper, and phosphorus, each, maximum, 0.05 per cent.
Tin or bismuth, absent or traces.
$2 to $8 per unit penalty for excess impurities beyond above allowance.

[2] Statement of W. F. Bleecker, Tariff Commission Denver Conference Report, p. 203 et seq.

Production of tungsten concentrate in the United States.[1]

[In tons of 2,000 lbs., 60 per cent WO_3.]

Year.	Production.	Average price per unit.	Year.	Production.	Average price per unit.
1901	179	$2.58	1910	1,821	$7.62
1902	184	3.00	1911	1,139	5.97
1903	292	2.48	1912	1,330	6.28
1904	740	4.00	1913	1,537	7.30
1905	803	5.57	1914	990	7.32
1906	928	6.27	1915	2,332	29.33
1907	1,640	9.05	1916	7,469	70.00
1908	671	5.72	1917	5,313	21.67
1909	1,619	6.32	1918		

[1] Compiled from Mineral Industry (compare with U. S. Geological Survey data on p. 23.)

The rise in the price of tungsten was fairly steady and rapid until the latter part of 1907. The first ore, known to have been mined in the United States and sold, was produced in 1900. At that time the price of tungsten trioxide was about $2 per unit in a 60 per cent concentrate. With the betterment in price the production increased slowly. In 1906 there was a remarkable increase and at the beginning of 1907 the price had risen to from $9 to $14 a unit. During the first part of 1907 business was good and there were large gains in production both in the United States and in foreign countries. Near the end of the year came the slump in the steel industry and the panic of 1907–8. The tungsten industry was temporarily crippled. Prices dropped to $5 a unit in the latter part of the year and continued at that level through the early part of the following year with production at a low ebb. Late in 1908 prices improved and the tungsten industry responded rapidly to an active demand. Production came back in 1909 to almost the high record of 1907 and in 1910 exceeded it. Then came another slump in the steel industry which was naturally reflected in the tungsten price and production. The period from 1912 up to the outbreak of the world conflict was one of slow recuperation from the 1911 setback. Improvement in price was not so rapid as in 1909, when the declining output from Australia strengthened the market. Burma began to produce tungsten in 1910 and immediately became an important factor in the world market. Only the more general recognition of the valuable properties of the black metal prevented an actual slump in prices. In the early part of 1914 there was a slack demand for tungsten and a tendency toward sagging prices, most sales being made on a basis of about $6.50 a unit. The outbreak of the war in August nearly paralyzed tungsten mining, and it was not until toward the end of the year that the demand quickened. Prices as high as $9 a unit were offered but throughout the year the price depended on the quality and quantity of ore and the urgency of the needs of buyers and sellers. The market was not general or active. Production fell off 40 per cent.

In the first quarter of 1915 the domestic production was at about the same rate as in 1914 and 60 per cent concentrates sold as low as $5.80 a unit. War orders were beginning to pour into the United States from England and France and caused a great demand for tungsten for high-speed cutting tools and other special steels. Then

the British Government placed an embargo on the exportation of tungsten ore and products from Burma and all British possessions. This embargo practically cut off all sources of foreign supply, importations of tungsten suddenly and almost completely stopped, so consumers turned to the domestic producers for their supplies. Prices began to soar; in May the value of tungsten concentrates had almost doubled and before the end of the year there was a frantic demand at $50 and $62.50 a unit. Mining of all known deposits were pushed and there was active prospecting for new deposits under the stimulus of record prices. As a result the 1915 output was nearly 140 per cent greater than that of 1914 and the greatest in the previous history of tungsten mining in this country and its value was nearly two and a half times as great as that for any previous year.

The boom that started in the latter part of 1915 expanded at an enormous rate in the early months of 1916 and reached its climax in April, when sales were made at the record price of $82.50 [1] a unit, compared with $7.32, the average price in 1914. This was the peak price, and before the middle of May the bottom dropped out of the market. Quotations at the end of May were less than half those of the preceding month, and buyers were taking only what they needed for immediate use. The hesitancy of consumers to make purchases together with a forced restriction in consumption allowed stocks to accumulate and the great activity of producers hastened the continued decline. In August the market steadied, while consumers satisfied their most pressing requirements at prices averaging only a little more than $25 a unit. The first week in September was marked by another precipitate decline, but the market soon found its level at about $17 and this price prevailed with a slight upward trend to the end of the year.

The abnormal market stimulus in the spring of 1916 aroused great excitement in all tungsten districts. Speculation in mines was even greater than in the ore and metal market. The wildest scramble for tungsten properties was that in Boulder County, Colorado. Clerks, waiters, farm hands, miners, and promoters all joined in a feverish search for showings of tungsten ore. The mad rush came when the ground was covered with snow, and little could be judged as to the value of the various claims and prospects, many of which changed hands several times a day. Thousands of dollars were paid for options, merely on hearsay evidence. Before the snow was gone and real prospecting and development could commence the bubble had burst. A number of "leasers" stayed and a few prospectors remained to work their claims, but most of the speculators and fortune seekers drifted away without in anyway adding to the output of the ore. Nevertheless the high prices of 1916 caused the reopening of many abandoned mines and brought about the discovery of some new deposits. After a few months development the output began to grow. On July 1, in only six months, an equivalent of over 3,000 tons of 60 per cent concentrates had been produced—more than the United States or any other country had ever produced in any 12 months previous to that time. The total production for the year was equivalent to 5,243 tons of 60 per cent concentrate, valued at $25,000,000.

[1] "In one instance, at least, upwards of $100 a unit was paid * * *." U. S. Tariff Commission, Denver Conference Report, p. 180.

The year 1917 was characterized by a reasonably steady market with a gradual upward movement. The monthly quotations which are given in the table below show a preference for scheelite, which developed in that year for the first time. Wolframite, especially ferberite, had hitherto been preferred to the lime mineral.

The tungsten ore market in 1918 started with a considerable accumulation of off-grade ore in New York. There were also some stocks of high-grade ore that was tied up by traffic conditions. The congestion of the railroads favored further accumulations. Western ore traveled, at times, two or three months before it reached its destination; and buyers, running short of material, preferred to buy spot New York delivery, which, in spite of delayed transit, reached Eastern points quicker than material sent from California and Nevada.[1] Chinese ore first became an active feature of the market in May and thenceforth was the important factor, though, on account of impurities, it was obtainable at a considerable reduction from the quotations of high-grade ore. The latter continued to sell, right up to the signing of the armistice, at prices of $24 and $24.50 for wolframite and $25 and $26 for scheelite, while the off-grade ore, which could be used only by plants employing special chemical (acid) treatment, was selling at from $5 to $6 per unit less.

Chinese ore deliveries in July to October ran up to about 1,200 ton per month, as compared with a total of only 200 tons in 1917. Imports from all countries were governed by the licensing system introduced by the American Iron and Steel Institute and which also covered the importation of all ferroalloys.

When the armistice was signed, November 11, the business in tungsten ore came almost to a stop. Government contracts were largely canceled and new business for peace purposes did not offset the loss of war orders. There was practically no market. Chinese ore continued to be imported in 1919 and supplies accumulated rapidly. While at first there was no regular market, quotations for spot delivery of Chinese ore later became adjusted at $6.50 and, later, $7 per unit. By June there was some dissipation of stocks of Chinese ore in this country and quotations for future delivery were placed at $8 per unit. Domestic mines were closed and American ore was no longer quoted.

Average monthly price of tungsten ore.[2]

[In dollars per unit, WO_3].

	1917		1918	
	Wolframite.	Scheelite.	Wolframite.	Scheelite.
January	17.14	17.50	24.75	26.00
February	16.80	17.50	24.50	26.00
March	17.17	17.77	24.00	24.55
April	17.86	19.04	24.00	24.50
May	19.10	20.94	24.00	24.13
June	20.80	23.50	24.00	24.00
July	23.44	25.68	24.00	24.00
August	24.66	26.50	24.50	25.05
September	23.92	26.00	24.50	25.35
October	24.00	26.00	25.00	26.00
November	26.00	26.00	(3)	(3)
December	25.24	26.56	(3)	(3)
Year	21.34	22.75	24.325	24.958

[1] Charles Hardy: Eng. Min. Journ. 107 (1919), p. 80.
[2] Engineering and Mining Journal quotations.
[3] No market.

DOMESTIC CONSUMPTION AND SOURCES OF SUPPLY.

The United States has become one of the largest consumers of tungsten in the world. While it is also one of the largest single producers, the domestic output has always been insufficient to satisfy the demands of consumers and the balance has to be imported. Most of the foreign supply came from Germany before the war in the form of both tungsten ore and as metal or ferrotungsten, but Germany was eliminated at the outbreak of the world conflict and the United States has fallen back on South America and China to supplement its domestic supplies. This change in sources of supply has also wrought a change in the character of the imports. Since there are no tungsten reduction works in South America, the tungsten supply in later years has been imported almost wholly in the form of ore to be reduced in this country. No tungsten is exported in the form of ore but there are appreciable quantities of ferrotungsten shipped out of the United States. In considering the needs of the United States, account should be taken of these exports of a comparatively crude form. A close approximation to recent actual consumption of tungsten is obtained in the following table. The data are based on 60 per cent concentrate, assuming that one ton of ferrotungsten is equivalent to two tons of concentrate.

Domestic consumption tungsten metal.[1]

(Expressed in short tons of 60 per cent concentrates: 1 ton ferro=2 tons concentrate.)

	1913		1917		1918 (7 months).	
	Tons.	Per cent.[2]	Tons.	Per cent.[2]	Tons.	Per cent.[2]
SOURCES OF SUPPLY.						
Imports:						
South America	.....	.....	3,560	37.4	2,126	30.8
China-Japan	.....	.....	831	8.7	1,931	28.0
Europe	1,705	52.3	121	1.3	50	.7
Mexico-Canada	12	.3	340	3.6	211	3.1
All other	6	.2	28	.3	27	.4
Total imports	1,723	52.8	4,880	51.3	4,345	63.0
Domestic production	1,537	47.2	4,633	84.7	2,550	37.0
Total supply	3,260	100.0	9,513	100.0	6,895	100.0
DISBURSEMENTS.						
Exports:						
France	(3)	(3)	316	3.3	694	10.1
Italy	(3)	(3)	1,328	14.0	280	4.1
England	(3)	(3)	310	3.2	.....	.....
Canada	(3)	(3)	20	.2	16	.2
All other	(3)	(3)	104	1.1	1	.....
Total exports	(3)	(3)	2,078	2.18	991	14.4
Net domestic consumption	3,260	100.0	7,435	78.2	5,904	85.6

[1] Data from Department of Commerce records, Geological Survey, and War Industries Board.
[2] Per cent of total supply.
[3] Included in "All others" in Department of Commerce records; exports only of ferroalloy and none prior to 1914.

The above table clearly shows the great increase in the consumption of tungsten in the United States, not only the consumption of concentrates that are merely made into ferrotungsten or tungsten

metal, but also the net consumption that goes into ultimate manufactures. The reduction of concentrate is a comparatively minor industry, and has developed in the United States, merely as a matter of convenience, just as Germany was formerly the brokerage market as well as a consuming market. The tungsten exports are wholly of metal or ferrotungsten. Since there is no tariff on tungsten ore, no records are kept of the portion of these exports derived from domestic and from foreign ore. If the ore were dutiable, most of these exports would have been "smelted in bond" or "exported with benefit of drawback."

The development of tungsten ore reduction for export is a direct result of the transfer of sources of supply, which are also indicated in the above table. Before the war, a large part of the foreign supply of tungsten came from Europe, especially Germany, and a large part of it was imported in the form of metal and alloy.

IMPORTS.

Before the war, Germany furnished the United States with about two-thirds of its imported supply of tungsten ores in addition to large amounts of tungsten metal and ferroalloy. Since Germany in normal times produced only 100 or 200 tons of tungsten ore a year, it is evident that Germany was not the country of origin of the large importations received in the United States, and that they were chiefly of ore produced in other countries and reexported from Germany. Until the outbreak of the war practically all the tungsten ore output of the world, with the exception of that of the United States and certain European countries, was sold to German buyers. The German firms were ready to purchase and treat ores containing objectionable impurities and low-grade material that British buyers would not touch and, naturally, a large part of the world output gravitated to this omnivorous market. Most of this ore was made into metal or ferrotungsten in Germany,[1] but the German ore buyers did some brokerage business and reshipped an important tonnage of the better class of ore, especially to the United States. In 1913 (fiscal year) the United States imported a total of 766 long tons of tungsten ore of which 600 long tons came from Germany.

Just preceding the war there was little demand for tungsten and imports fell off. The sudden demand in 1915 was only partially met by the increased domestic production. Germany was cut off as a source of supply because of the war. American consumers began to draw supplies direct from South American sources and in 1917 (fiscal year) over 80 per cent of the 3,832 tons of tungsten ore imported into the United States came from Peru, Chile, Argentina, Panama, and Ecuador. The imports from Panama were reshipments from Costa Rica, Ecuador, and Colombia. A large part of the imports from Chile, Peru, and Ecuador is of ore produced in Bolivia.

In general, imported ore has a higher tungsten content than the domestic product. A little of it grades down to 50 per cent WO_3, but the average is close to 60 per cent. It is rarely free from objectionable impurities. Much of it is impure stuff that can not be treated directly by the electric furnace plants, but is snapped up at low prices by companies equipped to treat it by chemical processes.

[1] In the 5-year period 1909–1913, the net imports of tungsten ore into Germany averaged 3,600 tons a year. Report of British Royal Commission.

IMPORTS BY COUNTRIES.

[Fiscal years.]

Imported from—	1912 [1]		1913		1914	
	Long tons.	Dollars.	Long tons.	Dollars.	Long tons.	Dollars.
Germany	233	115,307	600	300,867	125	78,709
Portugal	60	29,703	80	41,732	70	37,063
Spain	30	11,532	.....	.....	.....	.....
United Kingdom	48	23,212	68	34,557	22	13,519
Canada	.....	.....	12	6,789	.....	.....
Straits Settlements	.....	.....	6	2,684	.....	.....
All other	.....	.....	.....	.....	.....	.....
Total	371	179,754	766	386,629	217	129,291

Imported from—	1915		1916		1917		1918	
	Long tons.	Dollars.	Long tons.	Dollars.	Long tons.	Dollars.	Long tons.	Dollars.
Germany	11	8,692	.....	.....	.....	.....	.....	.....
Portugal	34	17,558	232	286,444	39	41,007	92	82,583
Spain	16	7,095	17	15,618	.....	.....	.....	.....
United Kingdom	175	84,891	31	23,361	.....	.....	.....	.....
Canada	.....	.....	.....	.....	.....	.....	11	36,000
Straits Settlements	.....	.....	.....	.....	.....	.....	.....	.....
Chile	19	10,531	786	2,017,145	1,407	2,013,411	1,358	1,364,461
Peru	154	72,553	800	1,223,001	1,092	1,073,001	1,528	1,455,863
Uruguay	6	2,340	24	27,242	.....	.....	.....	.....
Japan	24	11,492	362	791,568	286	374,404	965	1,157,329
Mexico	.....	.....	174	36,677	304	192,339	263	214,072
Argentina	.....	.....	373	684,677	449	1,062,604	251	371,227
Bolivia	.....	.....	75	203,767	.....	.....	65	82,542
Panama	.....	.....	3	7,600	140	144,558	23	26,143
Ecuador	.....	.....	.....	.....	5	5,300	10	12,559
China	.....	.....	25	12,768	50	42,747	759	723,935
Siam	.....	.....	25	22,778	50	48,877	20	17,166
All other	.....	.....	83	100,986	1	1,250	301	249,818
Total	439	215,152	3,010	5,453,632	3,823	4,999,498	5,646	5,793,698

[1] Included in "All other articles" prior to 1912.

IMPORTS FOR CONSUMPTION—REVENUE.

Fiscal years.	Rates of duty.	Quantities (long tons).	Values.	Duties collected.	Value per unit of quantity.	Actual and computed ad valorem rate (per cent).
1910 [1]	10 per cent	.....	272,311.00	27,231.10	.....	10.00
1911	do	.....	241,795.00	24,179.50	.....	10.00
1912	do	381.00	184,518.00	18,451.80	484.30	10.00
1913	do	766.37	386,629.00	38,662.90	504.50	10.00
1914 [2]	do	10.00	5,237.00	523.70	523.70	10.00
1914 [3]	Free	228.00	124,054.00	.....	544.10	.....
1915	do	439.00	215,152.00	.....	490.10	.....
1916	do	3,012.00	5,453,632.00	.....	1,810.30	.....
1917	do	3,733.00	4,999,498.00	.....	1,339.30	.....
1918	do	5,741.00	5,880,473.00	.....	1,024.30	.....

[1] Aug. 6, 1909, to June 30, 1910.
[2] July 1 to Oct. 3, 1913, under act of 1909.
[3] Oct. 4, 1913, to June 30, 1914, under act of 1913.

EXPORTS.

The United States is a large importer of tungsten ore, but not an exporter. Some of the California product was exported to Germany before the war,[1] but the amount was so small that no records are available. The exports shown in the domestic consumption table on a previous page were of ferrotungsten and calculated as concentrate merely for the purpose of comparison. Before the war little tungsten in any form was exported and the comparatively large exports of ferroalloy were due solely to war conditions, the United States having taken Germany's place to some extent as the immediate market for South American and Far Eastern ore.

Prices, tungsten-bearing ores (wholesale or retail)—Average of concentrates, 60 per cent WO_3.

[Data from The Mineral Industry.]

Kinds or grades.	Per short ton.	Kinds or grades.	Per short ton.
1908	$343	1913	$438
1909	379	1914	439
1910	457	1915	1,760
1911	358	1916	4,200
1912	377	1917	1,300

RATES OF DUTY ON TUNGSTEN-BEARING ORES.

Act of—		Tariff classification or description.	Rates of duty, specific and ad valorem.
Year.	Paragraph.		
1909	190	Tungsten-bearing ores of all kinds	10 per cent ad valorem.
1913	633	do	Free.

COURT AND TREASURY DECISIONS.

Tungsten ore or wolfram was held to be exempt from duty as a crude mineral under the act of 1897, and not dutiable as a metal unwrought nor as a metallic mineral substance in a crude state. (Hempstead *v.* Thomas, 122 Fed. 538 (T. D. 24506), reversing 115 Fed. 256; followed in G. A. 5400 (T. D. 24607).

[1] J. H. Mackenzie, Tariff Commission Conference Report, p. 18.

III. COMPETITIVE CONDITIONS.

The United States has never produced sufficient tungsten to satisfy the domestic demand. Stimulated by the great demand and consequent high prices of 1915–16, the production increased enormously; but even in 1916, the production increased at a slower rate than consumption. This relatively greater increase in consumption as compared with the domestic supply is not confined to the war period, but was in progress for several years preceding the outbreak of the Great War.

Table showing the approximate proportion of domestic tungsten ore requirements produced in the United States.

Calendar year.	Domestic production.[1]	Imports.[1]	Available supply.	Proportion of available supply produced in United States.
	Long tons.	*Long tons.*	*Long tons.*	*Per cent.*
1912	1,187	736	1,913	62.0
1913	1,372	401	1,773	77.4
1914	884	267	1,151	76.6
1915	2,082	1,370	3,452	60.3
1916	5,268	3,547	8,815	59.7
1917	4,137	4,357	8,494	48.7

[1] Production calculated into tons of 60 per cent WO_3. No data for correcting import tonnage to 60 per cent basis.

From 1912 to 1916, the domestic production exceeded the imports, but in 1917 and 1918, the consumption of foreign ore in the United States exceeded that from domestic mines. As has been noted elsewhere this increase in percentage of foreign ore is partly attributable to the fact that in recent years there have been no imports of ferrotungsten and some ferrotungsten has been exported. The main point, however, is that domestic production was handicapped because of the drop in price and the competition of foreign supplies.

The production of tungsten in every country passes through an early stage of comparatively cheap output from float ore and rich, easily-mined surface deposits. Practically no equipment or investment is required and the labor necessary to secure the ore is much less than is required at a later period, when the supply of ore must be got from underground mining. In this later period, the continued production of ore necessitates deep mining, more equipment, a comparatively heavy capital outlay for development, and generally higher operating costs.

Australia was in the first stage up to 1905. The United States was in it until 1915. Now, however, both countries are, broadly speaking, in the later stage. The output of both countries has dwindled, more rapidly in Australia because there the conditions are aggravated and have existed a longer time, but no less surely in the United States. The Boulder County (Colo.) district, which formerly supplied over 60 per cent of the domestic production is

stripped of easily mined ore and faces high costs and large investments if its production is to be maintained at anything like its former rate from its narrow veins and erratic ore shoots. In California the depletion is not so far advanced, but the exploitation of the large low-grade deposits upon which must depend the bulk of future production is delayed by the necessity of heavy capital expenditure. The general sentiment expressed by producers at the two conferences on tungsten held by this Commission was that capital was willing to assume the mining risk but hesitated to undertake the financing of tungsten ventures because it is not assured of a stable or adequate price for the product.

An important and growing factor in the American market is the supply of foreign ore. The price level has always been governed to a large extent by the cost of importing ore from other countries. The fear of a great influx of cheap foreign tungsten has been the deterrent to the investment of the requisite capital in many of the low-grade deposits of the United States.

The metallurgical treatment of tungsten ores is as efficient in the United States as in any country and far in advance of that in most other countries. While American labor is superior to that in any other large tungsten-producing region, it is necessarily much better paid. Where the output depends on a large amount of hand work as in mines of the Boulder County type, there is no possibility of producing ore so cheaply in the United States as in countries of low wages. The main dependence, therefore, of the United States are the low-grade, but probably extensive, deposits of the Southwest. American management and equipment have demonstrated their superiority in mining of low-grade properties on a large scale. Given an adequate tonnage, iron, copper, lead, and, more recently, molybdenum have been mined much more cheaply in the United States than in any other part of the world in spite of the high wages paid to the individual laborers. It is generally believed that there is an adequate supply of tungsten in these low-grade deposits, although it has not yet been fully demonstrated. If there is, the United States can hold its own against most of its competitors. The cost of production should not exceed greatly that of any country operating deep, low-grade mines. The only serious competition is the temporary production from surface ore, which can not be depended upon for a continuous supply but which does flood the market for a time with a disturbing effect on prices.

While the extremely pure American ore has invariably brought a better price in the past than the less pure foreign ores, the differential is rapidly becoming less because of the growing use of chemical treatment methods in place of electric furnace reduction of the crude concentrate. This differential is not likely ever to vanish altogether but it is only a small amount of protection.

During the war, embargoes and high ocean freights and insurance were the chief protection of the domestic producer. In the post-war period, these conditions have changed materially. The countries from which the United States imports the most tungsten are countries with which there is an active desire to foster trade. Tungsten ore may be used for a back haul cargo in place of ballast by vessels carrying American manufactures exported to these countries. Under these circumstances very low rates would doubtless be granted.

IV. MISCELLANEOUS.

REDUCTION OF TUNGSTEN ORE.

The greater part of the American and other ores free from objectionable impurities is reduced to ferro-alloy in electric furnaces, using carbon and the necessary fluxing agents. When ferrotungsten was first used a large proportion of it was made by reduction in crucibles, using the ore and carbon. This process generally yields a powder unless the ferro-alloy is very low grade and can be easily fused.

Impure ores can be treated by the so-called German process,[1] which was largely used in Germany before the war. There are several American plants now equipped for treating ores by this method. It is distinctly a chemical method, involving fusion with soda ash and coal, leaching out the sodium tungstate thus formed, and precipitating nearly chemically pure tungstic acid (H_2WO_4) by means of hydrochloric (muriatic) acid. The precipitate is dehydrated and reduced to metal, either in a stream of hydrogen or by heating with carbon in crucibles. Both methods produce tungsten powder. The second process is the commoner for use in steel, while the reduction with hydrogen is employed for making extremely pure metal for making incandescent lamp filaments.

To produce ductile tungsten for lamp filaments, the pure powdered metal is consolidated into rods under great pressure in an electric furnace in an atmosphere of hydrogen and at a temperature of about 2,850° C (below the melting point of tungsten under normal pressure). The bar thus formed is brittle and could not be drawn into wire. It is made ductile by hammering and rolling, in a specially constructed machine, at a temperature of about 1,200° C. and still in an atmosphere of hydrogen. After some 50 successive treatments in this machine, the bar is reduced to one-sixth its former size and has become sufficiently ductile. The drawing is done at a high temperature in diamond dies. The production of the ordinary filament requires drawing the metal through about 100 dies, which grow successively smaller until the desired diameter is reached.

OPINIONS OF PRODUCERS.

Tariff hearings, 1908–1909.—Abstract of brief by Walter M. Stein, president of the Primos Chemical Co., Primos, Pa., November 17, 1908:

"The cost of producing tungsten ore in this country amounts to $8 minimum per unit (of WO_3 per ton of 2,000 lbs.). Foreign ore coming in at a lower price forced American mines to shut down at certain periods. The tungsten ore conditions are similar all over the world, and the variation in costs of production depends entirely on the cost of labor at the mines, i. e., wages. Wages in foreign countries are

[1] For new commercial chemical method, see confidential files, U. S. Tariff Commission.

lower than in the United States, as shown by the following data. Labor in ore mining represents about 60 to 65 per cent of the total cost of production.

Europe:
  Portugal—
    Miners, 44 to 56 cents a day.
    Ordinary workmen, 30.4 to 36 cents a day.
    Women and boys, 16 to 19.2 cents a day.
  Spain—
    One mine, 110 workmen average 40 cents per day.
    Other mines, 50 t0 60 cents per day.
    Boys and women, 20 to 25 cents per day.
  Bohemia—
    Laborers, 35 to 45 cents per day of 10 hours.
    Miners, 75 cents per day.
South America:
  Argentina—
    Laborers, 20 to 25 cents per day.
    Miners, 75 cents per day, United States currency.
United States:
  Laborers, from $2 to $2.50 per day.
  Miners, from $3 to $4.50 per day.
  Mechanics, ore-mining centers, $5 per day.

On account of the difference in the cost of labor in the United States and in foreign countries, it would be but fair and reasonable to place a duty of 20 per cent ad valorem on tungsten ore, which is now on the free list." (Vol. II, p. 1430.)

Philip Bauer Co., of New York, writes relative to tungsten ores and concentrates, submitting a report made under date of October 14, 1908, by Frederick H. Minard, in which data are given regarding production costs and prices of tungsten ore. The article advocates free tungsten and is devoted principally to refuting statements made by W. M. Stein, president of the Primos Chemical Co., who advocates a tariff of 20 per cent. (Vol. II, p. 1491.)

York (Pa.) Metal & Alloy Co. submits statement relative to tungsten and molybdenum products under date of December 31, 1908, in which statements made by W. M. Stein, president of the Primos Chemical Co., regarding the cost of production are refuted, and the free entry of tungsten ores is advocated. (Vol. II, p. 1493.)

Brief of Primos Chemical Co. (1913), in reference to ferroalloys (abstracted):

"By far the greater portion of tungsten ores is produced in foreign countries. Through the sharp competition and low cost of production of the foreign ores it has not been possible to operate the mines in this country continuously, as in a sagging market the value of the ores soon falls below the cost of production in this country. There is between $3,000,000 and $5,000,000 invested in tungsten mines in the United States, which would be able to produce about one-fourth of the world's consumption, or enough to supply the entire domestic demand. But the world is being supplied from countries where wages are less than one-third of those paid in this country. A protest is made against the reduction of the duty provided in paragraph 190." (Vol. II, p. 1704.)

Brief of the Atolia Mining Co., in re tungsten-bearing ores, January 2, 1913 (abstracted):

"*Tungsten concentrates.*—A duty of 10 per cent ad valorem is at present imposed on this material under the tariff act of 1909; it is

proposed that this shall enter duty free. Tungsten ore is usually taken from the ground containing an average tungstic oxide content of not over 4 per cent. From this point it is subject to a process of concentration which involves labor and material. The buyers of tungsten concentrates require a product guaranteed to contain not less than 65 per cent tungstic oxide, and the cost of obtaining this per ton of concentrates for the last three years' operation of the Atolia has been about $306.60 per ton in labor and materials alone, exclusive of taxes, depreciation, amortization, and interest due on capital invested. It is contended it is working a hardship on the producer of tungsten to remove all protection on such so-called tungsten ore, if, at the same time, all the protection is not removed on the other forms in which tungsten can be imported, as it will naturally flow into the country by the lowest channel and defeat any hope of increasing the revenue, in addition to making the producer of tungsten concentrates bear practically the whole brunt of adjustment. It is urged that reduction in the tariff on tungsten ores, tool steel, tungsten powder, and ferrotungsten be made pro rata. If it is proposed to place tungsten ore on the free list then it should be defined as a natural product not containing over 5 per cent tungstic oxide.

"Tungsten ore has a gross content at best of about 4 per cent tungstic oxide, and a recoverable value with tungstic oxide at the price of $7 per unit (1 per cent) or about $21 per ton, 25 per cent being lost in the process of recovery. This is a raw material and could be imported free of duty without seriously affecting any interests. On the other hand, tungsten ore, as marketed (65 per cent concentrates), costs at least $300 per ton to prepare, and should be granted as much protection as any other manufactured article into which labor so largely enters." (H. R. Doc. No. 1447, 62d Cong., 3d sess., Vol. II, p. 1718.)

Brief of Atkins, Kroll & Co., by Comstock & Washburn: The brief refers to court and Treasury decisions, and gives statistics of imports and duty collected for annual periods 1907–1911. The rest of the article contains practically the same information as that given in the brief of the Atolia Mining Co. (H. R. Doc. No. 1447, 62d Cong., 3d sess., Vol. II, p. 1721.)

Brief of York Metal Alloy Co., York, Pa., January 16, 1912: The output of tungsten ores in Colorado is practically under the control of one concern, so much so that during the seven years in which the York Co. has been in business it has never been able to purchase any American "wolframite" with the exception of one instance of recent date when one car of 25 tons of low-grade ore was secured. Have had to depend entirely on foreign ore, and therefore the handicap of a 10 per cent duty works a hardship to them. (H. R. Doc. 1447, 62d Cong., 3d sess., Vol. II, p. 1721.)

Trade relations and the tungsten industry.—The major part of the imports of tungsten ore into the United States in 1916 to 1918 was derived from South American and Far Eastern countries. These are the countries with which the United States has been attempting to foster trade. In the case of a great many of these nations, the exports of tungsten ore to the United States bulk large in the value of the international trade. The placing

of a prohibitively high tariff on tungsten ore would result in the stopping of these exports to the United States and their transfer to other countries. Strong pressure [1] has been brought to bear by England to stop the growing trade in tungsten between Southern China and the United States. Whether this is merely an expression of the extraordinary British need of tungsten, or whether it has a deeper significance denoting a recognition that the tungsten trade may become the nucleus of broader trade relations, is a matter of conjecture. The fact, however, was that American importers were able to secure very limited supplies of south China ore because they have been very rarely able to secure the requisite permits from the British Government at Hongkong. Similar restrictions were placed on shipments from Siam. Speaking of the Hongkong situation, Consul General George E. Anderson at that city made the following report, dated November 9, 1917:

Because of war restrictions and other conditions, most of the ore heretofore exported has gone to Great Britain, and British regulations at this time make it difficult to ship south China ore to the United States. It is anticipated that this state of things will be remedied in the course of a short time, and in the meanwhile buyers for American steel manufacturers have been investigating the south China situation and have organized the work of gathering the available ore to such an extent that there is almost a boom in the business.

The course of the trade in Hongkong since the development of the south China fields commenced this year may be shown by the fact that the exports from Hongkong in June amounted to 60 tons, in July to 78 tons, and for the first half of August 92 tons, permits to ship to the United States being withdrawn about the middle of August. There is now on hand in Canton and Hongkong warehouses perhaps 500 tons of the ore ready for sending to the United States as soon as permission from the English Government covering transshipment at Hongkong can be obtained.

The following statements of Mr. Robert H. Hepburn, 921 South Forty-eighth Street, Philadelphia, Pa., apply to the South American situation:

The growing public realization of the importance of our trade relations with South America and the increasing demand that they be encouraged and developed imposes the duty of a careful consideration of the effects likely to follow the enactment and enforcement of possibly prohibitory trade legislation, and this applies especially to the importation of tungsten from Bolivia.

Bolivia is primarily dependent on tin and tungsten exports, and if we purpose establishing a permanent interchange of commodities with this country, this circumstance must be recognized. * * *

A slightly varying price (for tungsten) per unit—say $24 to $26, reasonably stabilized figures—would be ideal if practical and would enable producers and users to make definite calculations. * * *

Bolivian tungsten and tin can be sold readily in Europe with the natural consequence of imports following therefrom, but should we contribute to such a result, and in its effect blanket this and other trade relations with South American countries? * * *. It seems to me that the importation of tungsten and tin ores from Bolivia would be the very best protection of the Government against excess prices and still give generous profits to our mines and miners.

A market price of $24 to $26 per unit for tungsten would give only a fair profit to most of the miners in Bolivia, who pay for transportation from mine to railroad, over railroad to point of shipment, lighterage to vessel, freight to port of destination, insurance, etc., and to all these charges is added—owing to lack of American banking facilities—the cost of cabling moneys back for operating, etc., expenses. All this is certainly a right large protection for our own producers.

Should a market price of $28 to $30 per unit be allowed for tungsten concentrates, then a duty of $2 to $4 per unit could be paid by Bolivian miners and still send us ore.

[1] See confidential file, and Reports of Conference at San Francisco.

The above excerpts are from correspondence in reference to the war minerals bill and dated in the spring and early summer of 1918. (Copies of this correspondence are in the files of this commission.)

Another phase of the Bolivian tungsten situation is its complication with shipments of tin. Bolivia is the one source of supply for the tin smelting industry that has lately developed in the United States. Tin is as essential a commodity as tungsten and this country is barren of producing mines. Although it is the largest consumer in the world, the United States must rely wholly on foreign countries for its tin. There is active competition with foreign countries, especially England, for tin supplies, and as tin and tungsten are generally found together, a cessation of tungsten shipments may so prejudice foreign miners that they will also divert their tin ores to Europe.

Additional statements of producers have been abstracted for the T. I. C. unit on ferrotungsten (p. 15, No. 10). Many of these refer to tungsten ore and should be consulted in connection with the foregoing.

MINING LABOR CONDITIONS IN PORTUGAL.[1]

There is no class of labor in Portugal corresponding to the miners and mill men of America. All the workmen own small farms and only work in the mines when not engaged in harvesting. Carpenters, blacksmiths, tinsmiths, etc., turn out creditable work considering the tools they use, but they are not amenable to the introduction of modern tools or improved methods. Portuguese laborers' wages are low in comparison to those paid in the United States, as shown in table, but the fact that mechanical appliances operate better and at lower cost than any Portuguese hand labor must always be borne in mind.

Under proper supervision, and with the same mechanical equipment used in the United States, operating costs should be much less, on account of the low wages, but the substitution of hand methods, no matter how low the wages, for any mechanical appliance in Portugal, invariably results in higher costs and inferior grade of product.

Typical Portuguese mine wage scale, July, 1914.

Topographical engineer, per month		$49 00
Local superintendent, per month	$35.00–	105.00
Portuguese engineer, per month	56.00–	70.00
Bookkeeper, per month	28.00–	42.00
Mill captain, per day		.70
Mine captain, per day		.63
Guard, per day		.63
Miners, per day	.28–	.47
Trammers, per day		.25
Helper, per day	.11–	.14
Blacksmith, per day		.35
Carpenter, per day		.49
Women, per day	.14–	.21
Pack mule and driver, per day		.70
Bull cart and driver, per day		1.40

[1] Digest from an article entitled "The Mineral Industry in Portugal." Foote and Ransom. Eng. Min. Jour. 106 (1918), pp. 47–52.

The peasant or farmer class of Portuguese * * * is by nature slow, methodical, stupid and conscientious. The people are slow to learn anything new, and if it involves a change in the mode of operation from that to which they are accustomed, it is almost an impossible undertaking. * * * The natives also have a perverted inventive sense which prompts them to adjust engines and machinery, so that they can not run. Practically all the work in the mills is done by women. For the most part the women are better workers than the men and easier instructed.

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ASSOCIATIONS, ESTABLISHMENTS, IMPORTERS, EXPORTERS, TRADE JOURNALS, DIRECTORIES.

Engineering and Mining Journal.
Iron Trade Review.
Iron Age.
Mining and Scientific Press.

A large mailing list of tungsten producers and consumers was obtained from the United States Geological Survey (Mr. Frank L. Hess) preliminary to the conferences held by the United States Tariff Commission in Denver and San Francisco. A similar list can be obtained at any time. The uncertain condition of the industry is causing rapid changes in the names and a considerable percentage of former operators and buyers have gone out of the business and many others now engaged in the tungsten business may be expected to drop out in the near future. Since a practically complete and up-to-date list is always available on application to the Survey, none is given on this page.

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